

## **CUTTING TOOL INSERTS AND METHODS TO MANUFACTURE**

### **CROSS-REFERENCE TO RELATED APPLICATIONS**

This application claims priority on U.S. Provisional Application Serial No. 60/470,306, filed on May 14, 2003.

### **5 FIELD THE INVENTION**

[001] The present invention relates to cutting tool inserts, wherein an abrasive tip comprising an abrasive / superabrasive material is bonded to an insert body by mechanical forces generated through deformation of mating geometric features on the abrasive tip and insert body.

### **10 BACKGROUND OF THE INVENTION**

[002] Machining, cutting, sawing or drilling tools are often provided with removable inserts comprising conventional materials such as cemented carbides, ceramics (e.g.  $\text{Si}_3\text{N}_4$ ,  $\text{TiC-Al}_2\text{O}_3$  composites), and high-speed steel. As depicted in Figure 1, insert 1 is held firmly and locked into a tool holder 5 by a screw or other clamping mechanism

15 4. In machining operations, the insert is held in contact with the work piece and eventually wears to a point wherein it requires replacement. Inserts are, by definition, a disposable part of the machine tool system.

[003] Superabrasive materials containing diamond (e.g. polycrystalline diamond or PCD) and/or cubic boron nitride (e.g. polycrystalline cubic boron nitride, PCBN)

20 provide enhanced machining performance over conventional materials (tool life, surface finish, tolerance capability, etc.) and are also widely used as tool inserts. Due to the high material cost of superabrasives, fabrication techniques have been developed and optimized to reduce the usage (in  $\text{mm}^2$ ) of superabrasives on the insert. One such technique is the manufacture of "tipped inserts," which is also depicted in Figure 1. The

25 tipped insert consists of an insert body 3 and an abrasive tip 2 of superabrasive material, with the insert body being typically fabricated out of cemented tungsten carbide. The superabrasive tip 2 is attached to a corner or edge of the insert body by a brazing process. Brazing provides sufficient binding force to withstand the cutting forces and heat and is convenient for attaching small abrasive tips.

[004] Polycrystalline diamond (“PCD”) and cubic boron nitride (“PCBN”) are commonly manufactured bonded to cemented carbide to form a two-layer disk, with PCD or PCBN on one side and cemented carbide on the other. This is done to facilitate insert fabrication via braze attachment. The carbide side of the PCD or PCBN tips is easily  
5 brazed to carbide tip holders to make brazed inserts of the prior art. Directly brazing PCD or PCBN to carbide is challenging as the braze metal must spread over and bind quite dissimilar materials.

[005] Although the prior art brazing process does reduce the material cost of manufacturing superabrasive inserts, the process, and in particular the brazing operation  
10 itself, is labor intensive. In this process, as illustrated in Figure 2, an abrasive disc 11 is machined via EDM, EDG, or other processes, into a desired shape, e.g., an 80° triangle, forming an abrasive tip 12. A suitably sized pocket is ground in the insert body 13 to form the site for attaching the abrasive tip. The bottom rear edge of the abrasive tip may be chamfered to avoid stress buildup at the otherwise sharp corner where the abrasive tip  
15 will meet with the insert body 13. In the next step, a braze material, typically a metal paste, powder or foil, 14 is placed between the chamfered abrasive tip 15 and the pocketed insert body 16. A flux material may be applied to inhibit braze oxidation. The assembly is heated to a temperature above the liquidus of the braze material causing it to melt. Upon cooling, the metal freezes as a thin film binding the abrasive tip and insert  
20 body, forming the semi-finished insert, 17. The edges of the insert can then be ground to final dimensions and sharpness to produce the finished insert 18. The brazing process is labor intensive because the operator has to pay close attention to the joint interface, i.e., the abrasive tip, the braze interface layer, and the insert body, and reposition the materials, when molten, as necessary to assure good bonding. The ultimate location of  
25 the abrasive tip within the insert body and the quality of its attachment can be variable due to variable braze metal flow and the need for this manual positioning.

[006] A difficulty in the brazing process is that tool materials of different composition or grain size frequently require different brazing conditions, i.e., temperatures, times, braze metal formulations. Additionally, brazing dissimilar materials  
30 e.g., a cubic boron nitride tip to cemented carbide insert body requires special braze alloys and conditions capable of bonding both materials simultaneously in the same process

cycle. PCBN and PCD are known to be difficult to wet with brazes unless active metals, such as Ti or Fe, are incorporated into the metal formula. Such active metals are oxidation sensitive and may require use of an inert atmosphere or vacuum furnace, or very fast induction brazing, to improve the bond. They also require higher temperature  
5 that may lead to degradation of the superabrasive material.

[007] A further disadvantage of conventionally brazed inserts is that once formed, they cannot be heated above the sublimation or liquidus temperature of the braze metal in subsequent processing steps, such as, for example, chemical vapor deposition (CVD) coating of the insert. Low melting metals used in braze alloys, e.g., Sn, Zn, are  
10 volatile and the braze bond will be impaired and/or vacuum components contaminated by thermal treatment after brazing. Additionally, damage to the abrasive tip or insert body from the thermal expansion/contraction cycle during brazing is possible, requiring brazing temperature and time to be kept to a minimum. In some cases, rebrazing tips to correct braze flaws or regrind tips is not possible. Furthermore, heat generated at the tip  
15 during cutting may damage the braze attachment, allowing the tip to displace in the holder. This will disrupt the cutting operation.

[008] There are a number of references in the prior art for specialized tools that preclude the brazing requirements, including U.S. Patent No. 5,829,924 titled "Cutting Tool with Insert Clamping Mechanism," U.S. Patent No. 4,909,677 titled "Throw Away  
20 Cutting Tool," U.S. Patent No. 5,154,550 titled "Throw Away Tipped Drill Bit," and U.S. Patent No. 4,558,974 titled "Tool System for Precision Slotting." The prior art teachings rely on exact and complex geometrical configurations of an insert and tool holder to assure that the insert is securely gripped by the tool holder in operation. These references employ mechanical means of holding an insert in a tool holder and not holding  
25 an abrasive tip within the insert body itself.

[009] One solution for eliminating the brazing requirements in tipped inserts was recently made commercially available and is illustrated in Fig. 3. The insert system incorporates a reusable insert body, wherein the insert body itself acts as a clamp for holding an abrasive tip. As shown, the insert body is sectioned down the central vertical  
30 plane, connecting a set of jaws on one corner to a relief hole near the opposite corner. The relief hole and central vertical cut allow reversible movement of the jaws within the

horizontal plane of the insert body. The insert assembly is used with a specially designed tool holder that forces the insert back into a v-block when the clamping mechanism is tightened, squeezing the jaws on the insert body together and to firmly hold the abrasive tip in place during the machining operation. Removing the insert from the tool holder  
5 allows the insert body to spring back to its original state, allowing the jaws to open so that the tip can be removed and replaced. Abrasive tips are finish ground (i.e. chamfered, sharpened, and/or honed) before clamping into the insert body.

[010] Because of the reusable nature of the above-describe inserts, the deformation of the insert body and resultant clamping force must be reversible. If the  
10 jaws on the insert body are pried open or forced together to the extent that the insert body material yields at the corner opposite to the jaws, it will not spring back to its original state. Replacement abrasive tips would then have to be manufactured with progressively larger (or smaller) mating features to fit the insert body, posing significant complexity in manufacturing of the abrasive tips and application of the insert system. Another  
15 disadvantage is that the design limits the insert body to holding only one abrasive tip. Thus, the insert can not be indexed, i.e. rotated in the tool holder to use another corner as the cutting edge. It must be removed and refitted with a replacement abrasive tip, increasing the down time in operation. Lastly, with the abrasive tips being ground finished separate from the reusable insert body, dimensional differences between abrasive  
20 tips are imparted to the assembled insert. This may require recalibration of the positioning of the cutting edge with respect to the workpiece every time the abrasive tip is changed, else there is a risk of imparting dimensional differences in abrasive tips to the part being machined with resulting decreased dimensional capability and increased part scrap rate.

25 [011] There is a need for an improved, inexpensive, convenient, versatile insert system that eliminates the problems and costs associated with brazing without the increased complexity and limited utility of non-brazed inserts of the prior art. There is also a need for an insert that is simple and dimensionally precise, requiring minimal subsequent grinding for dimension control and sharpening. Lastly, there is a need for an  
30 insert system that enables abrasive tips and insert body materials to be selected without regard to their brazing compatibility, allows grinding of the assembled inserts, and

enables post processing at high temperatures (e.g., CVD coating or hardening via thermal processing).

## SUMMARY OF THE INVENTION

[012] The present invention relates to cutting tool inserts, wherein an abrasive  
5 tip comprising a hard material is bonded to an insert body by mechanical forces, said  
mechanical forces being generated through deformation of mating geometric features on  
the abrasive tip and insert body.

[013] The present invention further relates to a process to form cutting tool  
inserts, the process comprises the steps of bonding an abrasive tip comprising a hard  
10 material to an insert body by mechanical forces, specifically by deforming mating  
geometric features (or surfaces) on the abrasive tip and insert body.

## BRIEF DESCRIPTION OF THE DRAWINGS

[014] Figure 1 is an example of a tooling setup for turning in top and side view.  
The setup consists of an insert 1, comprising an abrasive tip 2 brazed to an insert body 3,  
15 which is held in a tool holder 5 by a clamping mechanism 4.

[015] Figure 2 is a diagram showing the multi-step process in forming a brazed  
tool insert of the prior art.

[016] Figure 3 is a photograph of a non-brazed insert of the prior art.

[017] Figure 4 is a diagram illustrating one embodiment of the process of the  
20 present invention for mechanically bonding an abrasive tip to an insert body, for forming  
an embodiment of the tool insert of the invention.

[018] Figures 5A and 5B show the top view of two embodiments of the  
invention, one interlocking embodiment and one non-interlocking embodiment.

[019] Figures 6A and 6B are photographs showing perspective views of inserts  
25 made by press-fit embodiements of the current invention.

[020] Figure 7 is a perspective view of another embodiment of the present invention, in which an abrasive tip and insert body have mating and interlocking circular features for mechanical bonding.

[021] Figures 8A, 8B, and 8C illustrate cross-sectional views of some of the  
 5 embodiments of the insert of the present invention. Figures 8D, 8E, and 8F illustrate top views of some of the embodiments of the invention.

[022] Figure 9 is a graph comparing the cutting life, in inches of steel machined per 0.001" of tip flank wear, of the pressed fit insert utilized an interlocking dovetail geometry in Figures 5 and 6, with brazed inserts in the prior art.

10 [023] Figure 10 is a graph comparing the machining performance of the tools of the present invention (as shown Figures 6-7) with the prior art tools, measured as inches of steel removed per 0.001" of flank wear.

#### DETAILED DESCRIPTION OF THE INVENTION

[024] As used herein, the term "*insert*" refers to pieces of tungsten carbide or  
 15 alternative cutting material mechanically held, brazed, soldered, or welded into position on dies or cutting tools, and discarded when worn out, others being fitted in their place. An example is illustrated in Figure 1. Also see *A Dictionary of Machining* (Eric N. Simmons, Philosophical Library, New York, 1972).

[025] As used herein, the term "*tool holder*" refers to the rigid body that holds an  
 20 insert or inserts firmly in place so that they can be utilized in a turning, milling, boring, cutting, or drilling application (see for example Figure 1, 5).

[026] As used herein, the term "*tipped insert*" refers to a cutting tool made up of a body (herein referred to as the insert body and depicted as item 3 in Figure 1) and a tip of some hard cutting alloy (herein referred to as the abrasive tip and depicted as item 2 in  
 25 Figure 1). Also see *A Dictionary of Machining*. Tipped inserts enable expensive materials to be economically used for cutting difficult materials, whereas in solid tool form they would cost far too much.

[027] As used herein, the term “*mating geometric features*” refers to features (or surfaces) on an insert body and abrasive tip that are capable of joining (or allow joining of) said insert body and abrasive tip by mechanical forces, for example, a tip comprising a male feature that is shaped to fit within a female feature of another piece.

5 The mating geometric features can be of similar contour, for example, a circular male feature fitting inside a circular female feature, or dissimilar contour, for example, a square male feature fitting inside a circular female feature. If dimensioned properly, the male and feature pieces can generate an interference fit.

[028] As used herein, the term “*interference fit*” refers to a size mismatch

10 between mating geometric features that results in deformation of one or both features when joined. The deformation, which can be elastic and reversible or plastic and irreversible, creates large normal and frictional forces between the parts.

[029] As used herein, the term “*reversible deformation*” refers to the material flow in a body caused by application of load that is below the yield strength of the

15 material comprising the body. When said load is removed (or, for example, press-fit bodies are separated), the body will return to its original dimensions.

[030] As used herein, the term “*irreversible deformation*” refers to the material flow in a body caused by application of load that is above the yield strength of the

20 material comprising the body. When said load is removed (or, for example, press-fit bodies are separated), the body will not return to its original dimensions.

[031] As used herein, the term “*interlocking geometric features*” refers to mating geometric features on the abrasive tip and insert body, wherein the cross-sectional area of the female feature is smaller at some distance  $x$  that is closer to the cutting edge on the abrasive tip than it is at some distance  $x + y$ , that is farther away from the cutting

25 edge of the abrasive tip. Illustrative examples of interlocking mating geometries are depicted in Figure 5A 41-44. Illustrative examples of mating geometries that are NOT interlocking are depicted in Figure 5B, 45-48.

[032] In the present invention, abrasive tips are mechanically bonded to insert bodies via forces generated through deformation of mating geometric features on the

30 insert body and abrasive tip, creating inserts of any variety of shape, size, or thickness,

attachable to a wide variety of tool holders for use in turning, milling, boring, sawing, and drilling applications. The novel mechanically bonded insert of the present invention may contain multiple abrasive tips (limited only by insert shape) and does not require external clamps, body wedges, nor fixture constraints.

5            [033] Abrasive Tips for use in the Tool Insert of the Invention. The abrasive tip may comprise any material that can be used in machining, cutting, or drilling applications, including but not limited to silicon nitride, silicon carbide, boron carbide, titanium carbide-alumina ceramics such as titanium carbide, fused aluminum oxide, ceramic aluminum oxide, heat treated aluminum oxide, alumina zirconia, iron oxides,  
10    tantalum carbide, cerium oxide, garnet, cemented carbides (e.g. WC-Co), synthetic and natural diamond, zirconium oxide, cubic boron nitride, laminates of these materials, mixtures, and composite materials thereof. These materials can be in the form of a single crystals or sintered polycrystalline bodies. Generally, the abrasive tip can be any material that is less deformable (harder) or more abrasion resistant than the material comprising  
15    the workpiece material, and will typically be more abrasion resistant than the material comprising the insert body.

             [034] In one embodiment of the invention, the abrasive tip has a thickness that is similar to that of the insert body. This combination allows use of the top and bottom cutting edges from one mechanically bound abrasive tip. These thick tips can be in the  
20    form of single crystals, sintered polycrystalline bodies, or laminate bodies with the abrasive material on the upper and lower layers of the assembly (Figure 6B, 72, 73, 75).

             [035] Abrasive compacts or blanks comprising polycrystalline diamond (PCD) or polycrystalline cubic boron nitride (PCBN) are commercially available from a number of sources, including General Electric Company under the trade names COMPAX<sup>®</sup> and  
25    BZN<sup>®</sup>, respectively. PCD and PCBN compacts may be self-bonded, or may include a suitable bonding matrix of about 5% to 80% by volume. The bonding matrix is usually a metal such as cobalt, iron, nickel, platinum, titanium, chromium, tantalum, copper, or an alloy or mixture thereof and/or carbides, borides, or nitrides or mixtures thereof. The matrix additionally may contain recrystallization or growth catalyst such as aluminum for  
30    CBN or cobalt for diamond.



[036] In one embodiment of the invention, the compacts are PCBN discs having a thickness of 1 to 15 mm. In a second embodiment, the PCBN compacts have a thickness of 1.6 to 6.4 mm. The forming of the compacts can be done via processes known to the art including Electro Discharge Machining (EDM), Electro Discharge Grinding (EDG), laser, plasma, and water jet. Geometries of cut pieces can be predetermined and computer controlled to maintain tight tolerances.

[037] In one embodiment, the PCBN blank is formed into shape via means of an abrasive water jet. In another embodiment of the invention, the PCBN blank is laser-etched at selected positions on the surface according to a predetermined computer controlled pattern, e.g., forming a polygonal shape with two of the sides forming a 80° triangle with 5.0mm cutting edge length, and the rest of the straight sides forming a zigzag shape for subsequent interlocking with the mating feature in the insert body.

[038] In one embodiment of the invention, the abrasive tip has a cutting edge with a length "a" of 0.5 mm to 25.4 mm, comprising angles of 20 to 90° in any plane of reference. In a second embodiment, the abrasive tip is of thickness of about 0.5 mm to 7 mm. The abrasive tip may be a circle, oval, octagon, hexagon, partial or complete ring shape (78 in Figure 8D), or any shape, or size used in cutting tools.

[039] Multi-tipped inserts according to the present invention may be formed with separate fitted abrasive tips as illustrated in Figures 8B, with tips 74 being inserted from opposite sides of the female feature on the insert body 84. Alternatively as illustrated in Figures 6B and 7, a single, dual-sided or solid (i.e. not supported) abrasive tip 31 with a thickness similar to that of the insert body 32 can be pressed all the way through the female feature to form cutting edges on the top and bottom of the insert.

[040] In another embodiment as illustrated in Figure 8E, the abrasive tips 79 may be inserted into the insert body 87 in 'holes' with no revealed tip at the edge or corner. The amount of hard tip material exposed for cutting would be determined by finish grind, thus eliminating the need to accurately pre-shape the tip prior to insert assembly, minimizing the amount of hard material that needs to be ground.

[041] Tool Insert of the Invention. The abrasive tip as described above may be used in tool inserts having a number of shapes or three-dimensional forms known in the

tooling art, including but not limited to ANSI insert shape designations of Square as illustrated in Figures 1 and 5, Triangle, Diamond (Rhombic as illustrated in Figure 8F), Parallelogram, Hexagon, Octagon, Pentagon, Trigon, Rectangle, Round as illustrated in Figure 8D with insert 86, donut shape and inverse, and Trapezoidal or any commonly  
5 used thickness or inscribed diameter size.

[042] In one embodiment, the tool insert body is ground to variety of shapes including hones, chamfers, wipers (multiple nose radii), rake angles, clearance angles, and the like known to the art without limit. In another embodiment of the invention, the tool insert body may include chip-breaking patterns, alignment holes, or chamfers within  
10 or on its body.

[043] The insert body may be made of any material, including but not limited to cemented carbides, steel, titanium, plastic, or ceramics, so long as it is strong and stiff enough to hold the abrasive tip rigidly subject to the forces and heat involved in the cutting operation, and that it does not crack in assembly.

15 [044] In yet another embodiment of the invention, the insert body comprises a high heat moldable thermoplastic material or thermoset material such as polyetherimide, polyamide, phenolic resin, and the like, having sufficient heat, ductile and strength properties to hold the tip with adequate compression during metal cutting.

[045] In one embodiment, the material comprising the insert body is a material  
20 that is heat resistant, stiff (high modulus), high strength, high ductility and easily formed to precise dimension and shape. In yet another embodiment, the insert body is a cemented carbide, comprising tungsten, titanium, or tantalum carbide particles, or a mixture thereof, which are bonded together with a binder of between about 6% to about 25% by weight of a metal such as cobalt, nickel, or iron, or a mixture or alloy thereof. In  
25 another embodiment, the insert body comprises a metallic material such as tool steel, stainless steel or titanium.

[046] In some instances wherein a stiff and hard material is used for the insert body, e.g., a ceramic or cemented tungsten carbide, and depending on the level of interference fit required to generate adequate holding forces, cracking can be induced in  
30 such materials. In these instances, an intermediate material or feature may be used to

sacrificially deform and reduce the tendency for hard and brittle insert bodies to crack upon assembly. As illustrated in Figure 8F, intermediate mating geometric features 90 and 91 are provided between the abrasive tip 89 and the insert body 88. The intermediate mating feature may comprise materials such as steel, titanium, or a grade of cemented carbide with a greater toughness than the material that makes up the insert body.

[047] The insert body of the invention and corresponding (female) feature may be formed via any process known to the art including EDM, EDG, laser, plasma, stamping, and water jet. In another embodiment of the invention, the holder can be formed via a process called Rapid Omni directional Compaction (ROC), which is a process for consolidating high-performance pre-alloyed powders into fully dense part. ROC process is disclosed in U.S. Patent No. 5,594,931, for a process to produce shapes with fine microstructures.

[048] Geometric Features of the Joint. There are an unlimited number of geometrical arrangements that can be utilized to bond the abrasive tip to the insert body in the inserts of the invention. Since the abrasive tip is more heavily abused during the application of the insert in a cutting process, it is preferable, but not required, to have the male, i.e. protruding, geometric feature on the abrasive tip and the mating female feature on the insert body. This places the abrasive tip material under compression rather than tension.

[049] Figures 4-8 illustrate various embodiments of the invention, in which the insert body (32, 49, 83-88) has an opening or female feature for receiving an abrasive tip (31, 41-48, 72-82 with mating geometrical features). As shown, the mating geometrical features can be either interlocking or non-interlocking. Figure 5 B is an example of non-interlocking features (45-48). Figures 5A, 6, and 7 are examples of interlocking features. In a number of applications, interlocking features are preferable over non-interlocking, as they provide additional holding force along all directions except that of insertion. Figure 6A is an example of an interlocking feature in the form of a dovetail joint.

[050] In yet another embodiment of the invention (not shown), the abrasive tip has a flaring tenon or a lip, which fits tightly with a mating socket on the holder for receiving the lip on the abrasive tip and forming an interlocking joint. In yet another

embodiment, the joint or mating surface, has rounded shape or circular pattern as illustrated in Figures 6B and 7, wherein the circular shape improves cutting rates and toughness of the joint by eliminating sharp corners or tight radii. In another embodiment, the abrasive tip 44 is in the form of a “wedge.” This geometry includes no sharp edges or tight corners and is thus convenient for attaching abrasive tips that are very small compared to the insert body.

[051] The area of the abrasive tip that is in contact with the insert body may be varied depending on the required mechanical holding force for the tip. For low-speed high cutting rate applications, and non-rigid machine tools, a larger holding force may be required. A large force requires larger contact area between abrasive tip and insert body and/or larger interference. Contact area can be adjusted with shape or simply dimension of that portion of the tip that will be used solely to hold the tip. The details of the abrasive tip, e.g., shape, angle, size, nose radius etc., are independent of the details of the insert body contact area used for bonding the tip. Dimensional and asperity irregularities e.g., burrs, roughness in the female feature of the insert body and on the abrasive tip can, in some cases, improve the mechanical grip

[052] In one embodiment of the invention the abrasive tip is tapered, i.e., the top or bottom side is smaller in dimension than the other. Taper improves alignment of the abrasive tip in the insert body female feature prior to press or shrink fit. Taper may be up to  $10^\circ$  or more, with 0.1 to 0.5 degrees preferred. Excessive taper lowers the average mechanical bonding force and concentrates it on certain regions the abrasive tip. The force may become too concentrated and crack the tip or too low and allow the tip to displace during cutting. Insufficient taper makes pre-fitting difficult, increasing the likelihood of misalignment and destruction of the holder upon press or shrink fit. The taper may be of any profile including but not limited to linear, rounded or curved, bilinear, or a combination of shapes.

[053] As illustrated in Figures 4, 6B, and 7, the female feature in the insert body may extend through the entire thickness, thus forming a hole or cutout section and allowing cutting edges to be on both the top and bottom of the abrasive tip. In this arrangement, a single abrasive tip can provide two times the number of cutting edges, i.e., the inserts of Figures 6B and 7 can have four cutting edges rather than two. Alternatively,

two abrasive tips 74 can be inserted into a single female feature on an insert body providing cutting edges on the top and bottom of the insert as depicted in Figure 8B. In another embodiment as illustrated in Figure 8C, the female feature (76, 77) only goes partially through the insert body. In yet another embodiment as illustrated in Figure 8A, the female feature (72, 73) does not penetrate the top or bottom surface of the insert body.

[054] The mating surfaces can be of simple geometry such as illustrated in Figure 8A between the tip 72 and the insert body 83, or of more complex geometry as in the threaded or barbed example also illustrated in the same Figure, between the tip 73 and the insert body 83. The mating direction of the female feature in the insert body and corresponding feature on the abrasive tip (72, 73) can be horizontal as illustrated in Figure 8A, or perpendicular as illustrated in Figure 7, or of any intermediate angle with respect to the plane of the insert.

[055] Process for Forming the Inserts of the Present Invention In the process of the present invention, the abrasive tip is joined with, i.e., mechanically bonded to, the insert body via primarily “mechanical” forces generated through deformation of mating geometric features on the insert body and abrasive tip. There may be other forces, e.g., adhesive forces, being present or generated in the process of joining the tip with the insert body. However, it is primarily the mechanical forces that securely hold the abrasive tip in the insert body. The mechanical forces can be generated by a number of techniques.

[056] In one embodiment of the invention, a surprisingly simple and effective technique is used as illustrated schematically in Figure 4, for a “press-fit” joint to secure the tip in the insert body. As shown in the Figure, abrasive tip 31 and insert body 32 having mating geometrical features are mechanically joined by lining up the mating geometries and pressing the pieces together via an applied force. Precise dimensional control of the mating geometric features is used to firmly hold the abrasive tip 31 in the insert body 32, forming the semi-finished insert 33. The semi-finished insert 33 can then be finish ground to final tool geometry 34 by standard methods known in the art.

[057] The insert body may be finish ground, polished, or otherwise further machined to remove irregularities, asperities etc, in its shape to aid in fit. The finish grinding or shaping of the insert body may be carried out using any of the processes

including but not limited to wire EDM (WEDM), milling, PM sintering, sintering and forging, forging, stamping, casting, and molding.

[058] In a second embodiment of the invention, the technique used is an “interference fit” for a holding force to be applied across the mating features on the abrasive tip and insert body. For an interference fit, the cross-sectional area of the male mating feature is slightly larger than that of the female feature at some point along the direction of insertion. Interference fits can cause reversible or irreversible deformation of the male and/or female mating feature, depending on the extent of the size mismatch and the yield strength of the mating materials. In practice, the amount of plastic deformation can be controlled through appropriate choice of this size mismatch.

[059] In certain applications, an interference fit that results in irreversible deformation of the insert body and/or abrasive tip is chosen as this ensures that the bonding force between the said abrasive tip and insert body is higher and more consistent (insert-to-insert) than if all deformation was elastic and reversible. If an abrasive tip that had been irreversibly press-fit into an insert body were removed and reinserted, the reinsertion would require less force than was required in the original assembly. The abrasive tip and/or insert body would have deformed irreversibly, reducing the dimensional mismatch between the male and female mating features after disassembly.

[060] It should be noted that irreversible deformation in the abrasive tip and/or insert body can also occur upon press fitting if the mating features have dimensional asperities, surface roughness, burrs, scratches, or other irregularities. These imperfections can result in local areas of high stress, exceeding the yield strength of the material and resulting in plastic deformation. For this reason, some level of dimensional asperity is desirable, as it increases the bonding force between the mating geometric features.

[061] In yet a third embodiment of the invention, the mechanical forces for bonding the abrasive tip to the insert body is generated by a “shrink fitting” technique. In this technique, mating geometric features are formed in the insert body and abrasive tip using processes known in the art. For shrink fitting, the dimensions of the female feature are left slightly smaller than those on the male feature. The female feature is then heated to a temperature that causes thermal expansion that is sufficient to fit the male feature

into the mating female feature. Upon cooling the assembly to room temperature, the abrasive tip and insert body will be firmly bonded together. Depending upon the dimensional mismatch of the mating features at ambient temperature, shrink fitting can also generate either reversible or irreversible deformation of, and holding forces between, the insert body and/or abrasive tip. Shrink fitting can also be achieved by means of a volume change in the material comprising the abrasive tip and/or insert body resulting from a phase transition.

[062] In yet a fourth embodiment of the invention, the abrasive tip and insert body are shaped concurrently in one operation, employing processes known in the art such as co-sintering or casting, insert or overmolding, or stamping, forging. In one embodiment of this technique, the female feature in the insert body is punched-through or stamped by the abrasive tip, i.e., analogous to a nail (the “abrasive tip”) in wood (the “insert body”), thus eliminating the need to pre-shape the female feature accurately.

[063] In one embodiment of any of the techniques above, the assembled insert is heated to further shrink and harden the insert body to increase compression after press-fit and cooling. In one embodiment of this process, the insert body is preheated or abrasive tips pre-cooled to alter their dimension prior to press fit and increase force by thermal-elastic strains.

[064] In yet another embodiment of any of the techniques above, a supplemental, third-body wedge may be added between the abrasive tip and insert body to, for example, prevent creep of the abrasive tip back out of the insert body and augment compression of the tip. In yet another embodiment, after mechanical bonding is established through methods described above, a spot weld (point of braze or solder) may be introduced to further assure that the tool tip is locked or held firmly in the holder.

[065] In yet another embodiment of any of the techniques above, a wedge in the form of a thin adhesive film or a thin metal foil or coating, e.g., Pb or Sn, is placed in the insert body prior to the press-fitting of the abrasive tip, thus ensuring void-free contact at all surfaces and augmenting the mechanical force by adhesion. Thin metal foils are commercially available from various sources including Wesgo, Allied Signal, and Vitta in thicknesses ranging from 0.0005 to 0.003 inches or more. In another example, an

adhesive paste, wax, or liquid is used instead of a foil to ensure void-free contact and add an adhesive force to the mechanical force holding the abrasive tip into the insert body.

Adhesive materials for use in ceramic bonding are commercially available from a number of sources, including Durit® Metal-Adhesive Powder/Liquid from Bonadent, GmbH,  
5 and Ceramabond™ from Aremco Products, Inc.

[066] Surface forces from adhesion, friction, or asperity yielding may be exploited to improve the strength of the bond between the abrasive tip and the insert body. However, surface forces may exceed the tensile strength of the abrasive tip or insert body, causing an undesirable crack or chip. In yet another embodiment of any of  
10 the techniques above, surface forces with resulting non-uniform stresses that could cause local chips and cracks are mitigated by the use of dry or wet lubricants such as graphite, hBN, oils, metallic soaps. These or other lubricants may be used to facilitate the fit of the abrasive tip into the insert body without reducing the wedge action and mechanical force due to material yield.

[067] In another embodiment of the technique of the present invention, the  
15 mechanical forces for bonding the abrasive tip to the insert body can also be generated by using a high-temperature moldable polymer as the insert body and directly molding the insert body around the abrasive tip. Subsequent chemical shrink from cure and/or thermal shrink create a mechanical force to hold the tip rigidly in the insert body. The  
20 molding can be any of the processes known in the art including casting, molding, and over-, co- or insert-molding and can be augmented by hydraulic compression. A molding process can eliminate assembly cost and the cost of precision shaping of the insert body and abrasive tip. In yet another embodiment of any of the techniques above, the tool insert can be further processed by thermal processing to further harden the insert,  
25 e.g., heating the tool insert at a temperature of at least 300°F. In still another embodiment of any of the above techniques, the additional processing step may include coating the tool insert via known coating techniques known in the art, e.g., a chemical vapor deposition technique, a physical vapor deposition technique, a thermal spray technique, a spraying technique using an air sprayer, a thermal injection technique, with a coating  
30 layer comprising at least one of a nitride, carbide, carbonitride, oxide, boride, or oxynitride of elements selected from a group consisting of B, Ti, Al, Si, Ga, refractory



hard metals, transition metals, and rare earth metals, or complexes and combinations thereof. In one embodiment, the coating layer is at least one of aluminum nitride, titanium aluminum nitride, titanium nitride, titanium aluminum carbonitride, titanium carbide, silicon carbide, and silicon nitride. In another embodiment, the coating is  
5 aluminum nitride, applied via a CVD process.

[068] Applications of the Mechanically Bonded Insert of the Invention. The mechanically bonded inserts of the present invention can be used in a number of tooling operations including but not limited to cutting tools; single-point tools, multiple-point tools such as a drill, a reamer, a milling cutter, a broach, a saw and a shank, and grinding  
10 tools. These include applications that normally use brazed inserts or conventional solid inserts (e.g., carbides, ceramics, etc.), as well as applications that typically cannot use inserts for a number of reasons, including braze quality.

[069] EXAMPLES. The examples below and as generally illustrated by the Figures are merely representative of the work that contributes to the teaching of the  
15 present invention, and the present invention is not to be restricted by the examples that follow.

[070] EXAMPLE 1. Two mechanically bonded inserts are prepared by the press-fit embodiment with mating and interlocking dovetail geometry similar to that pictured in Figure 6A. The abrasive tip material is available from General Electric  
20 Company of Worthington, OH, as BZN<sup>®</sup> HTM2100 blank in a carbide supported form with PCBN layer thickness of 0.039" and the overall thickness of 0.126". Abrasive tips with an 80° cutting corner and 5mm leg length are next cut from the blank by WEDM. The male, dovetail shaped mating feature is 0.149" wide, 0.059" deep, with 45° corners. The dovetail feature is WEDM cut with a 0.1° taper to facilitate fitting in the female  
25 feature of the insert body. The direction of the taper is from PCBN surface to carbide surface, so that the carbide side of the male feature is slightly smaller than the PCBN side. The insert body material is unhardened A2 tool steel with Rockwell Hardness A of 52 to 55. Female featured insert bodies are fabricated by WEDM out of steel plates with 0.126" or 0.189" thickness. After manually positioning the carbide end of the abrasive tip  
30 squarely in the opening of the female feature, the pieces are pressed together with a manual arbor press.

[071] For the comparable examples, conventionally brazed inserts are fabricated from cemented tungsten carbide insert bodies and the same PCBN material, using standard procedures familiar to those skilled in the art. The press fit and brazed inserts are then finish ground via standard insert grinding techniques to final specifications for a  
5 CNGA422 with 25° x 0.004" chamfer and a light hone.

[072] The inserts are evaluated in an accelerated turning test that simulates gear OD turning. All inserts are clamped onto a standard tool holder, with standard insertion into a machine tool turret. A notched steel cylinder made from 4340 hardened steel HRC62-65, six inches in diameter and two feet long, comprising 6 notches, is machined  
10 by lathe turning with the inserts. All tests are conducted using a 0.010-inch depth of cut, a 0.005 inch per revolution feed rate, with a cutting speed of 361 feet per minute. The inserts cut the steel workpiece in one-minute intervals, after which the flank wear in inches (an indicator of tool blunting or wear, inference to tool cutting life) are measured.

[073] The results of the machining test are illustrated in FIG. 9, indicating that  
15 the press-fit inserts of the present invention are comparable in performance to the brazed inserts of the prior art.

[074] EXAMPLE 2. In this example, several multi-tipped, mechanically bonded inserts of the present invention having mating circular features similar to that depicted in Figure 7 are prepared using the same procedures and materials as in Example  
20 1 unless indicated otherwise.

[075] Seven, two-tipped inserts are made from tungsten carbide supported BZN\* HTM2100 and insert bodies with two circular offset holes at opposite 80° corners. The offset holes are 0.088" in diameter and offset from the edge of the insert body by 0.026". Two mating abrasive tips with taper of 0.3 to 0.5 degrees are press-fit into each insert  
25 body to produce two-tipped inserts. A four-tipped insert as illustrated in Figure 6B is also fabricated with identical geometry by replacing the carbide supported HTM2100 abrasive tips with a specially prepared, solid unsupported version of HTM2100 with a thickness of 0.189". The exact dimensions of the insert bodies and abrasive tips are of varying levels of interference, in the range of 0.1 to 25lbs-force with an average interference of a  
30 positive 0.0002" and 0.0003" for depth and the ID of the tip respectively.

[076] These inserts are then finish ground to final specifications for a CNGA432 with 25° x 0.004" chamfer with a light hone and subjected to the same machining test described in EXAMPLE 1.

[077] Figure 10 compare performance data from the mechanically interlocked  
5 inserts of the present invention with conventionally brazed tools. The results also show that the press force and gap (in the abrasive tip / insert body fit) in the range selected play no major role in tool life, within normal test uncertainty. Furthermore, the inserts of the present invention, within errors in the test, give comparable performance to the brazed inserts of the prior art.

10 [078] EXAMPLE 3. A press-fit assembly taken from EXAMPLE 2 is heated at 800°C for 2 hrs in flowing argon. The furnace tube is not fully purged of ambient air, so the insert is visibly oxidized but not chipped or cracked. A visual inspection shows that the abrasive tip still being held strongly in the insert body.

[079] The thermally treated press-fit insert is next tested in the same lathe  
15 turning test described in EXAMPLE 1. The wear rate of the thermally-treated press-fit insert is comparable to the unheated press-fit assemblies in Examples 1 and 2, i.e., with no deleterious increase in flank wear, thus demonstrating the feasibility of thermal processing of the novel press-fit insert assembly of the invention.

[080] Some of the preferred embodiments have been set forth in this disclosure  
20 for the purpose of illustration. However, the foregoing description should not be deemed to be a limitation on the scope of the invention. Accordingly, various modifications, adaptations, and alternatives may occur to one skilled in the art without departing from the spirit and scope of the claimed inventive concept.

[081] All of the patents, patent applications, articles, and texts mentioned above  
25 are incorporated herein by reference.